JHR 82: 1–19 (2021)
doi: 10.3897/jhr.82.60054
https://jhr.pensoft.net

RESEARCH ARTICLE

JOURNAL OF Hymenoptera RESEARCH
A peer-reviewed open-access journal
The International Society of Hymenopterists

Checklists of the Hymenoptera of Canada, Alaska and Greenland – Introduction

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Academic editor: M. Ohl | Received 26 October 2020 | Accepted 21 January 2021 | Published 29 April 2021

http://zoobank.org/45E01FB1-42F4-47F6-8943-86C38C484391

Citation: Bennett AMR (2021) Checklists of the Hymenoptera of Canada, Alaska and Greenland – Introduction. Journal of Hymenoptera Research 82: 1–19. https://doi.org/10.3897/jhr.82.60054

Abstract

The distribution of described, extant species of the insect order Hymenoptera recorded from northern North America will be published in a series of ten checklists. In total, 9250 species in 27 superfamilies and 84 families are recorded from Canada, the state of Alaska (USA) and Greenland (Denmark). Within northern North America, 8933 species are recorded in Canada (96.6% of the total species), Alaska has 1513 (16.4%) and Greenland has 205 (2.2%). Within Canada, Ontario is the province with the most species recorded (5322, 57.5% of all species in northern North America), followed by Quebec (4207, 45.5%) and British Columbia (4063, 43.9%). At the family level, Ontario has 82 of the 84 recorded families, Quebec has 76 and British Columbia has 71. The most species-rich superfamilies in northern North America are Ichneumonoidea (4438 species, 48.0% of the total); Apoidea (1438, 15.5%) and Chalcidoidea (1246, 13.5%). The largest families are Ichneumonidae (3201 species, 34.6% of the total), Braconidae (1237, 13.4%), Tenthredinidae (573, 6.2%), Eulophidae (379, 4.1%) and Pteromalidae (309, 3.3%). Overall species richness of the Hymenoptera in northern North America is compared with surveys in Russia, Germany, Finland and the British Isles.

Keywords

Ants, bees, northern North America, parasitic and predatory wasps, sawflies, species distributions

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Introduction

The order Hymenoptera constitutes one of the largest orders of insects, including such well-known groups as ants, bees and social wasps. The order has slightly more than 154,000 described, extant species in the world (Huber 2017) which places it fourth in species richness, behind beetles (Coleoptera) with 386,755 species (Bouchard et al. 2017), flies (Diptera) with 157,971 species (Courtney et al. 2017) and moths and butterflies (Lepidoptera) with 157,761 species (Goldstein 2017). However, estimates of the total number of species, including undescribed ones, suggest that Hymenoptera may be the most speciose order. Our lack of taxonomic knowledge of the group, especially in tropical regions is the reason it appears at present to be less speciose than the other three orders (Forbes et al. 2018). The diversity of Hymenoptera was well-summarized in one sentence by LaSalle and Gauld (1993): "the order Hymenoptera is very large, very important and very poorly known."

As with most insects, the vast majority of Hymenoptera species go unnoticed by humans and generally have little or no direct impact on them (Huber 2017). However, some are of great benefit, the most obvious example being the honey bee, *Apis mellifera* Linnaeus, for its importance in pollination of many food plants, and production of honey for which world exports in 2019 amounted to US$1.99 billion (Workman 2020). Many other Hymenoptera are pollinators e.g., bumble bees and many species of solitary bees and wasps, whereas others are scavengers and aerators of soil e.g., ants, or regulators of arthropod pests (LaSalle 1993). The regulators consist of predators (solitary and social wasps, many ants) but mostly of parasitoids, a diverse group that comprises the majority of Hymenoptera. Parasitoids use one host individual to complete their development and, in so doing, almost invariably kill it (Wheeler 1923). Conversely, a minority of species of Hymenoptera are pests, including some species of sawflies, a grade of seven extant superfamilies (Taeger et al. 2018) comprising the most ancient lineages of Hymenoptera (Peters et al. 2017), which are almost entirely herbivorous (Goulet 1993). In addition, some Hymenoptera species are hyperparasitoids, parasitizing other parasitoids and therefore having potential negative impact on species that are beneficial biological control agents (Tougeron and Tena 2019). Other species are primary parasitoids of beneficial herbivores used for biological control of weeds (Paynter et al. 2010). Perhaps the group of Hymenoptera most commonly ascribed pest status are females of most social Aculeata which may sting in self defense and quite regularly cause human deaths, e.g., in the United States of America, an average of 62 human deaths per year due to wasp and bee stings were reported between 2000 and 2017 (National Vital Statistics System 2019).

Distributional checklists of insects of northern North America have been published for several major orders. Bousquet (1991) produced a checklist of the beetles (Coleoptera) of Canada and Alaska, with a second edition about 20 years later (Bousquet et al. 2013). Maw et al. (2000) published a checklist of the bugs (Hemiptera) of Canada and Alaska and Pohl et al. (2018) produced a checklist of the moths and butterflies (Lepidoptera) of Canada and Alaska. For Hymenoptera, the "Catalog of the Hymenoptera in America North of Mexico" (Krombein et al. 1979) is the most recent

distributional survey, treating species up to 1972–1976 (the cut-off date depending on the superfamily) but distributions were generally summarized as ranges such as "N.S. w. to B.C.", which means that Krombein et al. (1979) is not a comprehensive distributional checklist. It is also at least 45 years out of date. Other surveys of Canadian Hymenoptera include Masner et al. (1979) in "Canada and its Insect Fauna" (Danks 1979). This study listed numbers of described species by family, reporting a total of 6028 species, although the approximately 80 species of Eurytomidae were inadvertently omitted and the numbers of described species of Platygastroidea, Ceraphronoidea, Bethylidae, Cynipoidea and Pompilidae appear to have been overestimated based on the numbers of described species then known. Thus, in 1979, approximately 6000 described species of Hymenoptera were reported for Canada. Bennett et al. (2019) compiled species numbers for Canada from the unpublished checklists that form the basis of the current series, updating the described species numbers to 8757. They did not provide distributions by Canadian provinces and territories, and commented only briefly on relative species richness across the region using ecozones. Bennett et al. (2019) did include estimates of predicted total species richness of Hymenoptera families in Canada based on sequencing of the DNA barcode region of cytochrome oxidase I (*COI*) and using the Barcode Index Number (BIN) criterion of Ratnasingham and Hebert (2013) that 2% sequence divergence is indicative of species differences. The current series of checklists only reports described, recorded species, but discussion of estimated species richness is provided in the individual papers treating particular taxa. It is the purpose of the current series of papers to present the first complete, distributional checklist of the described, extant species of Hymenoptera of northern North America, including species records from Alaska, Greenland and all Canadian provinces and territories.

Methods

Sources of data

The starting point for this study was an inventory of the species of Hymenoptera in the Canadian National Collection of Insects, Arachnids and Nematodes, Ottawa (CNC). Additional credible, distributional records from the literature were then added to the CNC list. In this way, records are substantiated by evidence, either collection- or literature-based. All relevant taxonomic studies were consulted, as well as distributional surveys that included northern North American records, ecological and biological studies plus any other published works that provided substantiated geographic information on Hymenoptera in the northern Nearctic region. The aforementioned "Catalog of the Hymenoptera in America North of Mexico" (Krombein et al. 1979) was a major source of records. Several databases and other online resources were invaluable for helping mine the literature and verify nomenclature for particular groups: ECatSym (Taeger et al. 2018) for sawflies, Universal Chalcidoidea Database (Noyes 2019) for Chalcidoidea, Taxapad (Yu et al. 2016) for Ichneumonoidea, Catalog of Sphecidae

sensu lato (Pulawski 2020) for apoid wasps (Apoidea: Spheciformes), Discoverlife (Ascher and Pickering 2020) for bees, Antcat (Bolton 2020) for ants. The Greenland records were taken mostly from relevant chapters in Böcher et al. (2015). In addition, so as to provide complete coverage of the northern part of the Nearctic region, records were also included from the 242 km^2 French Overseas Collectivity of Saint Pierre and Miquelon islands located 25 km from the southern coast of Newfoundland. These were obtained from the TAXREF database (Gargominy et al. 2020) managed by the Muséum national d'Histoire naturelle, Paris. We only became aware of these records during the peer-review of the manuscript and so unlike all other records in the series, we were not able to verify these records by examination of specimens or evaluation of published studies. Nevertheless, a summary is provided in the Results and Discussion. Apart from the CNC, specimens in other collections were consulted as listed in each checklist. Checklists of some taxa, especially those treating Aculeata and sawflies, have a larger percentage of records based on specimens in collections other than CNC. This is a reflection of the fact that these groups have been studied by researchers at many institutions meaning that more collections have authoritatively-identified specimens. In contrast, Canadian research on the parasitoid groups of Hymenoptera, e.g., Ichneumonoidea, Chalcidoidea and other microhymenoptera, has mostly been done by staff at the CNC meaning that most other entomology collections in Canada do not have large numbers of well-identified, northern North American specimens of these taxa (although exceptions do occur, as noted in particular checklists). For this reason, other collections were only sparingly consulted for the parasitoid checklists. Other sources of information for some checklists include substantiated photographic records from iNaturalist (iNaturalist 2020), Bugguide (Bugguide 2020) and records in the Centre for Biodiversity Genomics (University of Guelph) Barcode of Life Database (BOLD) (Ratnasingham and Hebert 2007). For the latter, some credible records were included based on the use on BINs together with examination of photographs to support the identification. If photographs showing diagnostic features were not available or there was any uncertainty about the validity of the BIN-based identification, then specimens were borrowed to check identifications; otherwise the records were excluded. Only described, extant species are included in the checklists. Subspecies are generally not included because in many instances their morphological differences and geographic ranges overlap, making their definitions arbitrary. Undescribed taxa, specimens identified only to genus, and fossil species are excluded.

Assessing credibility of records

With respect to published records, we critically evaluated publications to determine their accuracy. The credibility of literature references was mostly evaluated by checking whether specimens were expertly identified, e.g., by an acknowledged expert of the taxon, as well as by knowledge of the previous distribution of the species (for new records) and the level of evidence provided to support each record. For example, detailed studies treating the biology of species were generally considered more credible than references that lacked any accompanying supporting evidence. For records based on specimens,

relative credibility for identifications was judged based on the following categories of specimens, in descending order of trust: primary types, secondary types, non-types used in revisions, non-types identified by experts in the taxon, non-types identified by non-experts in the taxon. If there was a significant doubt with respect to a record (whether specimen- or literature-based) it was omitted. Introduced species, whether deliberate or accidental, are included in the checklists if there is evidence that they have established, e.g., recovery of a biological control agent in subsequent years following release. Biological control agents that were introduced, but not subsequently recovered are not included, nor are accidental, extralimital (= adventive) species that have been collected only once or a few times in northern North America, but for which there is no evidence that they have established breeding populations. Species that had established populations, but are now apparently extinct from an area, e.g., the apple sawfly *Hoplocampa testudinea* (Klug) on Vancouver Island, British Columbia (Vincent et al. 2019), are included in the list with a note stating that local extinction is suspected.

Format

The format chosen for this study is similar to the checklist of British and Irish Hymenoptera (Broad 2014) in that it will be published as a series of papers instead of one comprehensive volume. The reason for this is because of the huge size of the order, the large number of authors working on different parts of the series and the specialized nature of the taxa (most readers will be interested in only one checklist). There was concern that if an attempt were made to produce the series as one checklist, those parts that were finished sooner would have to wait until all parts were completed which would be unfair to those authors who had finished their lists. Once published, all checklists will be gathered together in a single location (a "Topical collection" on the Journal of Hymenoptera Research website) which will facilitate the location and downloading of the entire series. The first two checklists, treating 1) sawflies; and 2) Chalcidoidea and Mymarommatoidea, are published concurrently with this introductory paper. They comprise just over 20% of the total species. The remaining eight checklists (see Table 1) are expected to be published by 2023. All of the checklists differentiate

Table 1. Taxa covered in the Hymenoptera of Canada, Alaska and Greenland checklist series showing how superfamilies and/or families are grouped into checklists.

	Taxa
1.	Sawflies: Anaxyeloidea, Cephoidea, Pamphilioidea, Siricoidea, Tenthredinoidea, Xyeloidea
2	Chalcidoidea, Mymarommatoidea
3.	Ceraphronoidea, Cynipoidea, Evanioidea, Stephanoidea, Trigonalyoidea
4.	Chrysidoidea
5.	Diaprioidea, Platygastroidea and Proctotrupoidea
6.	Apoidea: Spheciformes: Ammoplanidae, Ampulicidae, Astatidae, Bembicidae, Crabronidae *sensu stricto*, Mellinidae, Pemphredonidae, Philanthidae, Psenidae, Sphecidae
7,	Apoidea: Apiformes
8.	Vespoidea *sensu lato*: Formicoidea, Pompiloidea, Scolioidea, Sierolomorphoidea, Tiphioidea, Thynnoidea, Vespoidea *sensu stricto*
9.	Braconidae
10.	Ichneumonidae

between new and previously published records. In determining whether records were new, the authors tried to search all literature sources, but there may be cases in which previously published records were overlooked. We do not consider records previously published if they are only present in online webpages such as iNaturalist or BugGuide or from online institutional databases.

Presentation of data

Because this is a series of checklists, not catalogues, only the current, valid species names, including author and year, are listed. In general, synonyms are not provided except in cases in which there has been a relatively recent change to a species name that was prevalent in the literature. If there is doubt about the validity of a species, e.g., if a species complex is suspected, this may be noted below the species name. In addition, other notes pertaining to species or their distributional records may be provided, e.g., explanations why particular records are omitted because misidentifications were discovered. If omission of a distributional record leads to the complete omission of a previously recorded species from Canada, Alaska and Greenland, a note may be provided under the respective genus (or subfamily if a previously published generic record is omitted). Distributions are indicated in the checklists using acronyms of 18, mostly political regions of northern (mostly north of 45° latitude) North America. This style closely follows that of previous checklists of insects in Canada and Alaska, e.g., Bousquet (1991) for beetles and has the advantage that it avoids the need for column headings on each page. For practical purposes, the province of Newfoundland and Labrador is divided into the island of Newfoundland and the region of Labrador on mainland Canada. The acronyms used for the regions are: **CAN** = Canada, **AK** = Alaska (USA), **GL** = Greenland (Denmark), **SPM** = Saint Pierre and Miquelon (France). Within Canada, the regions are **AB** = Alberta, **BC** = British Columbia, **LB** = Labrador, **MB** = Manitoba, **NB** = New Brunswick, **NF** = Newfoundland island, **NS** = Nova Scotia, **NT** = Northwest Territories, **NU** = Nunavut, **ON** = Ontario, **PE** = Prince Edward Island, **QC** = Quebec, **SK** = Saskatchewan, **YT** = Yukon Territory. These regions are shown in Fig. 1. Table 2 is a summary of the numbers of described, recorded species of Hymenoptera in northern North America, totalled for each family by region. The totals for Saint Pierre and Miquelon are not included in Table 2 because of the small number of records and the fact that we were not able to verify the records by examination of specimens. The regions in Table 2 are listed approximately from West to East beginning with northernmost continental North America (AK to NU) and then across more southern Canada (BC to NF), to Greenland, which provides a pictorial representation of the taxon's overall west-to-east distribution across northern North America. Fig. 2 displays the numbers of described, extant species in each of the major taxa of Hymenoptera in northern North America as a percentage of total species number. These species numbers and distributions are the exact counts at the time of original submission of the manuscript (October 1, 2020), with the exception of Chalcidoidea that was updated to December 31, 2020 in order to incorporate some additional records. Because

work is still continuing on most checklists, the numbers in these checklists will likely differ from those in this paper, but the differences will be enumerated in each checklist.

Classification

Superfamily and family classification of sawflies follows Goulet and Huber (1993) except Xiphydriidae is placed in Siricoidea, and Anaxyelidae is placed in its own superfamily following Taeger et al. (2018) (both these families were unplaced in Goulet and Huber 1993). Cynipoidea family classification follows Ronquist (1999), specifically that the former families Charipidae and Eucoilidae are considered subfamilies of Figitidae. Diapriidae is removed from Proctotrupoidea to form Diaprioidea and Ismarinae is raised from a subfamily of Diapriidae to a family within Diaprioidea following Sharkey et al. (2012). The classification of Platygastroidea is consistent with the concepts of Masner (1993) and Talamas et al. (2019) which recognizes Scelionidae and Platygastridae as opposed to the former being a synonym of the latter (Sharkey 2007). Recognition of both families is similar to the classification in recent checklists such as Buhl et al. (2016) for Britain and Ireland and Timokhov (2019) for Russia, at least with respect to the described taxa present in northern North America. Vespoidea *sensu lato* mostly follows Branstetter et al. (2017) who divided the group into 7 superfamilies and 13 families, except we only recognize 12 families – Myrmosidae is once again considered part of Mutillidae (Brothers and Lelej 2017). Chalcidoidea follows Heraty et al. (2013) except Megastigmidae is separate from Torymidae (Janšta et al. 2018). Finally, classification of the apoid wasp families ("Spheciformes") follows Sann et al. (2018) who raised the subfamilies (as well as one tribe and one subtribe) within Crabronidae to family status.

Results and discussion

A total of 9250 described, extant species of Hymenoptera in 84 families in 27 superfamilies are listed for Canada, Alaska and Greenland (Table 2, Fig. 1). Of these, 8933 species in the same 84 families are listed from Canada (96.6% of all species), 1513 species (16.4%) in 46 families from Alaska and 205 species (2.2%) in 16 families from Greenland. To place these numbers of species in a historical perspective, the current number of species recorded in Canada represents a 48.8% increase from the approximately 6000 species reported in 1979 once omissions and overestimates in Masner et al. (1979) are taken into account. For Alaska, Krombein et al. (1979) recorded about 600 species of Hymenoptera, therefore the current survey is an increase of approximately 152%. The summary of the entomofauna of Greenland (Böcher et al. 2015) totalled 190 described species of Hymenoptera in 15 families (not counting Aphelinidae, Trichogrammatidae and Proctotrupidae for which family records were based on specimens not identified to species). Hymenoptera specimens from Greenland in Canadian collections are not extensive which, along with the short duration

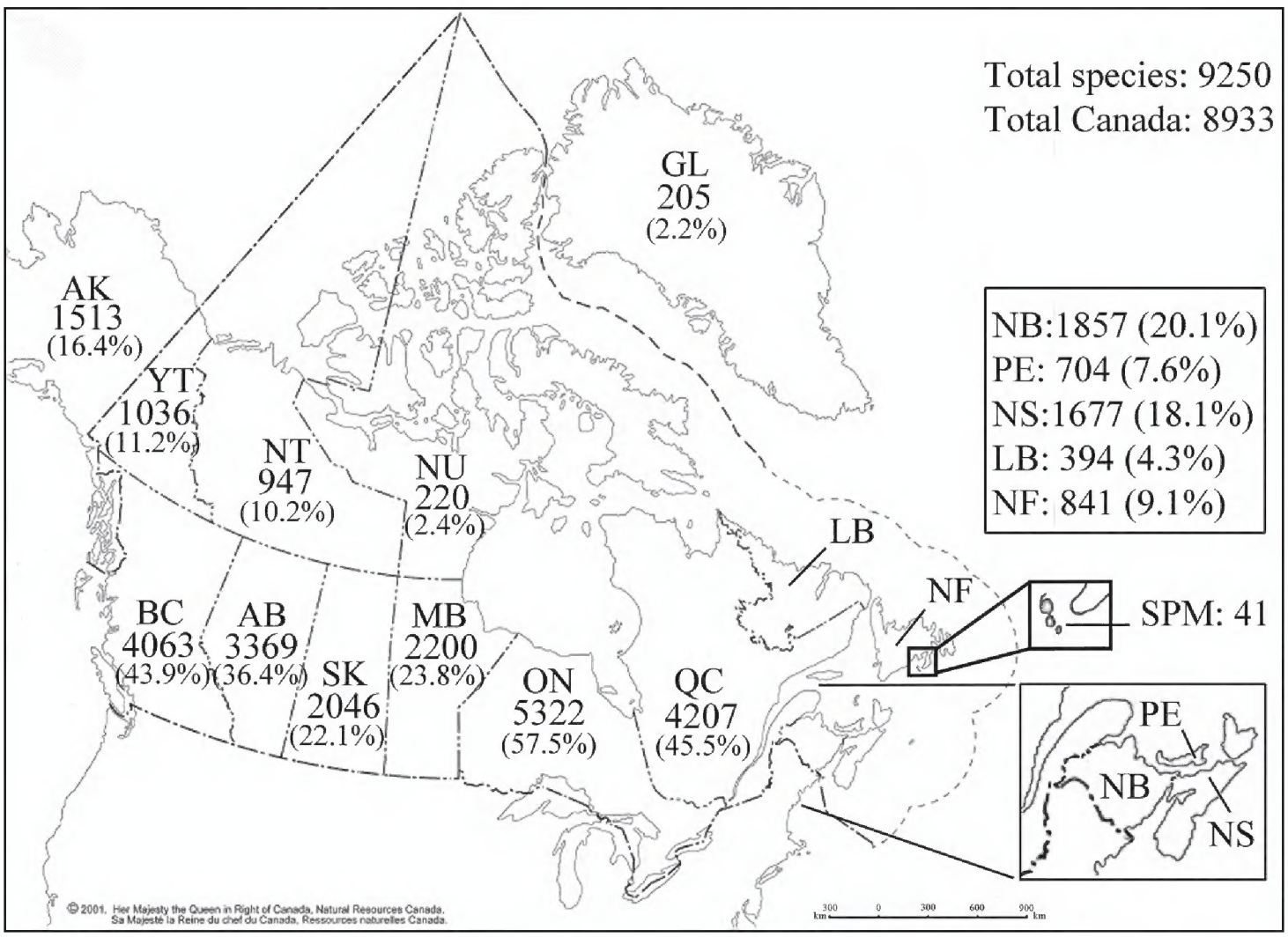

Figure 1. Map of Canada, Alaska, Greenland and Saint Pierre and Miquelon showing number of described, recorded Hymenoptera species and percentages of total species for each region. Canada is comprised of all regions except for Alaska, Greenland and Saint Pierre and Miquelon. See the Presentation of data section under Methods for the acronyms of the regions treated in the checklist.

between surveys, accounts for the limited difference (7.9%) between this survey and Böcher et al. (2015). The fact that over 100 morphospecies of Ichneumonidae have been collected from nearby Ellesmere Island, Nunavut (Timms et al. 2013) implies that additional collecting and taxonomic description of Hymenoptera from Greenland may yield many new records.

The TAXREF database (Gargominy et al. 2020) lists 41 species from Saint Pierre and Miquelon from the following groups: 14 sawflies (1 Cimbicidae, 1 Diprionidae, 1 Pamphiliidae, 2 Siricidae, 9 Tenthredinidae), 1 Chalcidoidea, 9 Ichneumonidae, 7 bees (2 Andrenidae, 3 Apidae, 1 Colletidae, 1 Halictidae), 1 apoid wasp (Spheciformes), 3 ants and 6 vespid wasps. All species recorded from the collectivity are also present in eastern Canada (most are present in Newfoundland). The fact that the nearby Island of Newfoundland has 841 species recorded implies that more species of Hymenoptera would be found in the collectivity if additional sampling was done.

In terms of the composition of the species of Hymenoptera in northern North America, just over three quarters of the described, extant, recorded species (77.0%) belong to three superfamilies: Ichneumonoidea (4438 species: 48.0% of the total), Apoidea (1438 species: 15.5%) and Chalcidoidea (1246 species: 13.5%) (Table 2

Table 2. Described, recorded species of Hymenoptera in Canada, Alaska and Greenland totalled for each superfamily, family and selected higher groups in each region. CAN+AK+GL column shows total species for northern North America. See Methods (Presentation of data) for description of distributional acronyms and Fig. 1 for a map of their locations. Sawflies (previously suborder Symphyta) comprise the first seven superfamilies. Apocrita comprises all other superfamilies.

Taxon	CAN +AK +GL	CAN	AK	YT	NT	NU	BC	AB	SK	MB	ON	QC	NB	PE	NS	LB	NF	GL
SAWFLIES	**758**	**729**	**183**	**92**	**111**	**43**	**308**	**248**	**158**	**249**	**471**	**411**	**209**	**45**	**203**	**64**	**94**	**7**
ANAXYELOIDEA	**1**	**1**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Anaxyelidae	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
CEPHOIDEA	**12**	**12**	**0**	**0**	**0**	**0**	**7**	**3**	**3**	**5**	**7**	**6**	**1**	**0**	**5**	**0**	**1**	**0**
Cephidae	12	12	0	0	0	0	7	3	3	5	7	6	1	0	5	0	1	0
ORUSSOIDEA	**5**	**5**	**0**	**0**	**0**	**0**	**2**	**0**	**1**	**1**	**4**	**2**	**0**	**0**	**0**	**0**	**0**	**0**
Orussidae	5	5	0	0	0	0	2	0	1	1	4	2	0	0	0	0	0	0
PAMPHILIOIDEA	**55**	**54**	**6**	**1**	**1**	**0**	**25**	**15**	**10**	**16**	**40**	**35**	**25**	**3**	**19**	**2**	**8**	**0**
Pamphiliidae	55	54	6	1	1	0	25	15	10	16	40	35	25	3	19	2	8	0
SIRICOIDEA	**28**	**28**	**4**	**3**	**3**	**2**	**14**	**11**	**10**	**10**	**17**	**15**	**10**	**5**	**11**	**4**	**4**	**0**
Siricidae	20	20	3	3	2	2	13	11	9	8	10	10	7	4	8	3	4	0
Xiphydriidae	8	8	1	0	1	0	1	0	1	2	7	5	3	1	3	1	0	0
TENTHREDINOIDEA	**641**	**613**	**172**	**84**	**104**	**41**	**251**	**213**	**133**	**217**	**393**	**346**	**172**	**37**	**166**	**58**	**80**	**7**
Argidae	29	29	4	3	4	0	10	9	4	11	21	19	10	2	9	1	2	0
Cimbicidae	10	9	4	4	4	1	6	6	4	4	7	6	3	0	3	2	4	0
Diprionidae	25	25	2	0	0	0	8	4	3	10	21	15	11	2	7	2	4	0
Pergidae	4	4	0	0	0	0	0	0	0	0	3	3	0	0	2	0	0	0
Tenthredinidae	573	546	162	77	96	40	227	194	122	192	341	303	148	33	145	53	70	7
XYELOIDEA	**16**	**16**	**1**	**4**	**3**	**0**	**8**	**6**	**1**	**0**	**10**	**7**	**1**	**0**	**2**	**0**	**1**	**0**
Xyelidae	16	16	1	4	3	0	8	6	1	0	10	7	1	0	2	0	1	0
APOCRITA	**8492**	**8204**	**1330**	**944**	**836**	**177**	**3755**	**3121**	**1888**	**1951**	**4851**	**3796**	**1648**	**659**	**1474**	**330**	**747**	**198**
CERAPHRONOIDEA	**52**	**48**	**2**	**0**	**0**	**0**	**12**	**1**	**1**	**4**	**22**	**22**	**1**	**0**	**2**	**0**	**0**	**2**
Ceraphronidae	**27**	27	0	0	0	0	9	0	1	1	10	10	1	0	1	0	0	0
Megaspilidae	**25**	21	2	0	0	0	3	1	0	3	12	12	0	0	1	0	0	2
CHALCIDOIDEA	**1246**	**1214**	**113**	**69**	**78**	**7**	**440**	**355**	**207**	**245**	**852**	**566**	**257**	**79**	**223**	**13**	**56**	**26**
Aphelinidae	**38**	38	0	0	0	0	11	9	6	5	27	20	8	1	8	0	1	0
Azotidae	**1**	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Chalcididae	**39**	39	3	2	1	0	13	9	14	16	29	17	5	1	2	0	1	0
Encyrtidae	**110**	100	4	2	3	1	33	23	16	14	69	35	23	5	22	1	5	10
Eucharitidae	**8**	8	1	1	1	0	4	7	3	2	6	3	3	2	1	0	0	0
Eulophidae	**379**	374	43	23	34	2	133	108	61	87	285	191	107	18	89	5	28	6
Eupelmidae	**28**	28	0	0	0	0	8	6	3	4	20	8	4	3	3	0	0	0
Eurytomidae	**87**	87	4	5	3	0	35	27	21	20	65	44	9	8	11	2	0	0
Leucospidae	**1**	1	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0
Megastigmidae	**21**	21	3	2	2	1	11	5	3	4	12	10	3	2	3	2	3	0
Mymaridae	**96**	94	12	5	8	0	29	19	4	9	67	46	10	10	18	0	1	1
Ormyridae	**9**	9	0	0	1	0	2	2	0	2	7	4	2	0	3	0	0	0
Perilampidae	**20**	20	0	2	0	0	8	9	8	3	14	13	5	4	5	0	0	0
Pteromalidae	**309**	295	36	22	20	3	111	98	57	58	186	136	64	21	49	3	16	9
Signiphoridae	**1**	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Tetracampidae	**4**	4	0	0	0	0	0	1	0	0	4	3	1	0	0	0	0	0
Torymidae	**60**	59	3	3	3	0	28	20	9	14	41	22	8	2	5	0	1	0
Trichogrammatidae	**35**	35	4	2	2	0	13	11	1	6	17	13	4	1	3	0	0	0
CYNIPOIDEA	**149**	**141**	**17**	**8**	**6**	**0**	**56**	**54**	**23**	**29**	**84**	**40**	**20**	**5**	**15**	**1**	**4**	**6**
Cynipidae	**75**	75	2	3	0	0	22	22	13	17	46	17	3	3	4	1	2	0
Figitidae	**69**	61	15	5	5	0	32	31	10	11	35	20	14	2	8	0	2	6
Ibaliidae	**4**	4	0	0	1	0	2	1	0	1	2	3	3	0	3	0	0	0
Liopteridae	**1**	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
DIAPRIOIDEA	**189**	**185**	**39**	**33**	**22**	**12**	**90**	**55**	**18**	**42**	**144**	**124**	**38**	**2**	**41**	**10**	**16**	**5**
Diapriidae	**181**	177	39	33	22	12	88	54	17	42	137	119	34	2	38	9	14	5
Ismaridae	**8**	8	0	0	0	0	2	1	1	0	7	5	4	0	3	1	2	0
EVANIOIDEA	**30**	**30**	**3**	**1**	**3**	**0**	**15**	**5**	**3**	**7**	**21**	**16**	**7**	**4**	**9**	**0**	**0**	**0**

Taxon	CAN +AK +GL	CAN	AK	YT	NT	NU	BC	AB	SK	MB	ON	QC	NB	PE	NS	LB	NF	GL
Aulacidae	**18**	18	1	1	2	0	9	2	1	5	12	10	4	2	6	0	0	0
Evaniidae	**4**	4	0	0	0	0	0	0	0	0	4	1	0	0	0	0	0	0
Gasteruptiidae	**8**	8	2	0	1	0	6	3	2	2	5	5	3	2	3	0	0	0
ICHNEUMONOIDEA	**4438**	**4205**	**903**	**510**	**450**	**126**	**1858**	**1566**	**859**	**944**	**2405**	**2117**	**834**	**272**	**708**	**188**	**480**	**147**
Braconidae	**1237**	1169	178	81	72	17	424	288	198	272	729	529	231	45	180	20	100	27
Ichneumonidae	**3201**	3036	725	429	378	109	1434	1278	661	672	1676	1588	603	227	528	168	380	120
MYMAROMMATOIDEA	**2**	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**1**	**1**	**0**	**0**	**0**	**0**	**0**
Mymarommatidae	**2**	2	0	0	0	0	0	0	0	0	2	1	1	0	0	0	0	0
PLATYGASTROIDEA	**168**	**162**	**3**	**3**	**7**	**0**	**33**	**27**	**17**	**19**	**124**	**83**	**45**	**1**	**21**	**1**	**4**	**6**
Platygastridae	**71**	70	2	1	0	0	7	5	3	4	45	25	19	0	7	1	1	1
Scelionidae	**97**	92	1	2	7	0	26	22	14	15	79	58	26	1	14	0	3	5
PROCTOTRUPOIDEA	**73**	**73**	**34**	**29**	**15**	**4**	**46**	**32**	**18**	**19**	**45**	**44**	**9**	**4**	**9**	**8**	**15**	**0**
Heloridae	**2**	2	0	1	0	0	1	1	1	1	2	2	1	1	0	0	0	0
Pelecinidae	**1**	1	0	0	0	0	0	0	0	1	1	1	0	1	0	0	0	0
Proctotrupidae	**67**	67	34	28	15	4	45	31	17	16	39	39	8	2	9	8	15	0
Roproniidae	**2**	2	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0
Vanhorniidae	**1**	1	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0
STEPHANOIDEA	**2**	**2**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Stephanidae	**2**	2	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0
TRIGONALYOIDEA	**4**	**4**	**0**	**0**	**0**	**0**	**1**	**1**	**1**	**0**	**3**	**1**	**0**	**0**	**1**	**0**	**0**	**0**
Trigonalyidae	**4**	4	0	0	0	0	1	1	1	0	3	1	0	0	1	0	0	0
ACULEATA	**2139**	**2138**	**216**	**291**	**255**	**28**	**1203**	**1025**	**741**	**642**	**1148**	**782**	**436**	**292**	**445**	**109**	**172**	**6**
APOIDEA	**1438**	**1437**	**132**	**186**	**173**	**15**	**814**	**692**	**513**	**424**	**745**	**516**	**297**	**218**	**308**	**62**	**107**	**3**
APOIDEA: APIFORMES	**909**	**908**	**95**	**108**	**101**	**15**	**519**	**370**	**303**	**279**	**448**	**322**	**209**	**169**	**238**	**44**	**76**	**3**
Andrenidae	**202**	202	18	20	17	0	123	87	76	69	94	74	50	39	50	10	14	0
Apidae	**235**	234	33	31	27	11	124	87	75	63	112	73	44	40	56	17	20	3
Colletidae	**57**	57	7	8	6	0	26	24	18	29	36	25	14	13	19	5	7	0
Halictidae	**198**	198	10	13	19	1	85	83	69	55	117	77	61	50	71	6	17	0
Megachilidae	**214**	214	27	36	32	3	160	88	64	61	88	70	38	27	41	6	18	0
Melittidae	**3**	3	0	0	0	0	1	1	1	2	1	3	2	0	1	0	0	0
APOIDEA: SPHECIFORMES	**529**	**529**	**37**	**78**	**72**	**0**	**295**	**322**	**210**	**145**	**297**	**194**	**88**	**49**	**70**	**18**	**31**	**0**
Ammoplanidae	**8**	8	0	0	0	0	4	3	1	0	1	2	0	0	0	0	0	0
Ampulicidae	**2**	2	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0
Astatidae	**20**	20	1	6	6	0	17	15	10	5	7	5	0	1	1	0	0	0
Bembicidae	**86**	86	3	7	9	0	48	53	29	23	42	26	14	4	9	0	0	0
Crabronidae	**196**	196	19	33	30	0	101	121	83	56	121	79	34	23	33	9	19	0
Mellinidae	**2**	2	0	0	0	0	0	1	1	1	2	1	0	0	0	0	0	0
Pemphredonidae	**58**	58	7	18	11	0	42	36	14	8	33	23	13	6	9	1	7	0
Philanthidae	**61**	61	1	2	2	0	27	35	27	22	30	17	7	3	4	0	0	0
Psenidae	**36**	36	6	8	10	0	17	21	17	12	28	20	11	4	6	6	5	0
Sphecidae	**60**	60	0	4	4	0	39	37	28	18	31	19	9	8	8	2	0	0
CHRYSIDOIDEA	**183**	**183**	**19**	**30**	**22**	**0**	**90**	**88**	**54**	**48**	**112**	**57**	**39**	**13**	**20**	**3**	**13**	**1**
Bethylidae	**29**	29	2	0	1	0	9	6	3	3	20	9	4	1	4	0	1	0
Chrysididae	**102**	102	13	23	16	0	64	67	41	32	46	30	15	10	10	1	4	0
Dryinidae	**50**	50	4	6	5	0	16	15	9	12	44	17	18	2	5	2	8	1
Embolemidae	**2**	2	0	1	0	0	1	0	1	1	2	1	2	0	1	0	0	0
VESPOIDEA *sensu lato*	**518**	**518**	**65**	**75**	**60**	**13**	**299**	**245**	**174**	**170**	**291**	**209**	**100**	**61**	**117**	**44**	**52**	**2**
FORMICOIDEA	**229**	**229**	**29**	**20**	**16**	**10**	**127**	**117**	**84**	**82**	**118**	**110**	**41**	**19**	**63**	**25**	**25**	**1**
Formicidae	**229**	229	29	20	16	10	127	117	84	82	118	110	41	19	63	25	25	1
POMPILOIDEA	**140**	**140**	**13**	**28**	**19**	**1**	**86**	**64**	**39**	**45**	**83**	**47**	**25**	**14**	**22**	**6**	**6**	**0**
Mutillidae	**26**	26	0	0	0	0	15	13	7	10	7	3	1	1	2	0	0	0
Pompilidae	**107**	107	13	27	18	1	67	48	31	33	72	43	24	13	19	6	6	0
Sapygidae	**7**	7	0	1	1	0	4	3	1	2	4	1	0	0	1	0	0	0
SCOLIOIDEA	**3**	**3**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**2**	**1**	**0**	**0**	**0**	**0**	**0**	**0**
Scoliidae	**3**	3	0	0	0	0	1	0	0	0	2	1	0	0	0	0	0	0
SIEROLOMORPHOIDEA	**2**	**2**	**0**	**1**	**0**	**0**	**1**	**2**	**1**	**0**	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Sierolomorphidae	**2**	2	0	1	0	0	1	2	1	0	2	0	0	0	0	0	0	0
TIPHIOIDEA	**31**	**31**	**0**	**0**	**0**	**0**	**12**	**5**	**4**	**1**	**14**	**6**	**2**	**0**	**2**	**0**	**0**	**0**

Taxon	CAN +AK +GL	CAN	AK	YT	NT	NU	BC	AB	SK	MB	ON	QC	NB	PE	NS	LB	NF	GL
Tiphiidae	**31**	31	0	0	0	0	12	5	4	1	14	6	2	0	2	0	0	0
THYNNOIDEA	**6**	**6**	**0**	**1**	**0**	**0**	**4**	**2**	**1**	**1**	**3**	**3**	**0**	**1**	**0**	**0**	**0**	**0**
Chyphotidae	**1**	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Thynnidae	**5**	5	0	1	0	0	3	1	1	1	3	3	0	1	0	0	0	0
VESPOIDEA *sensu stricto*	**107**	**107**	**23**	**25**	**25**	**2**	**68**	**55**	**45**	**41**	**69**	**42**	**32**	**27**	**30**	**13**	**21**	**1**
Rhopalosomatidae	**1**	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Vespidae	**106**	106	23	25	25	2	68	55	45	41	68	42	32	27	30	13	21	1
TOTAL SPECIES	**9250**	**8933**	**1513**	**1036**	**947**	**220**	**4063**	**3369**	**2046**	**2200**	**5322**	**4207**	**1857**	**704**	**1677**	**394**	**841**	**205**
TOTAL FAMILIES	**84**	**84**	**46**	**48**	**46**	**17**	**71**	**66**	**65**	**66**	**82**	**76**	**61**	**51**	**63**	**33**	**39**	**16**

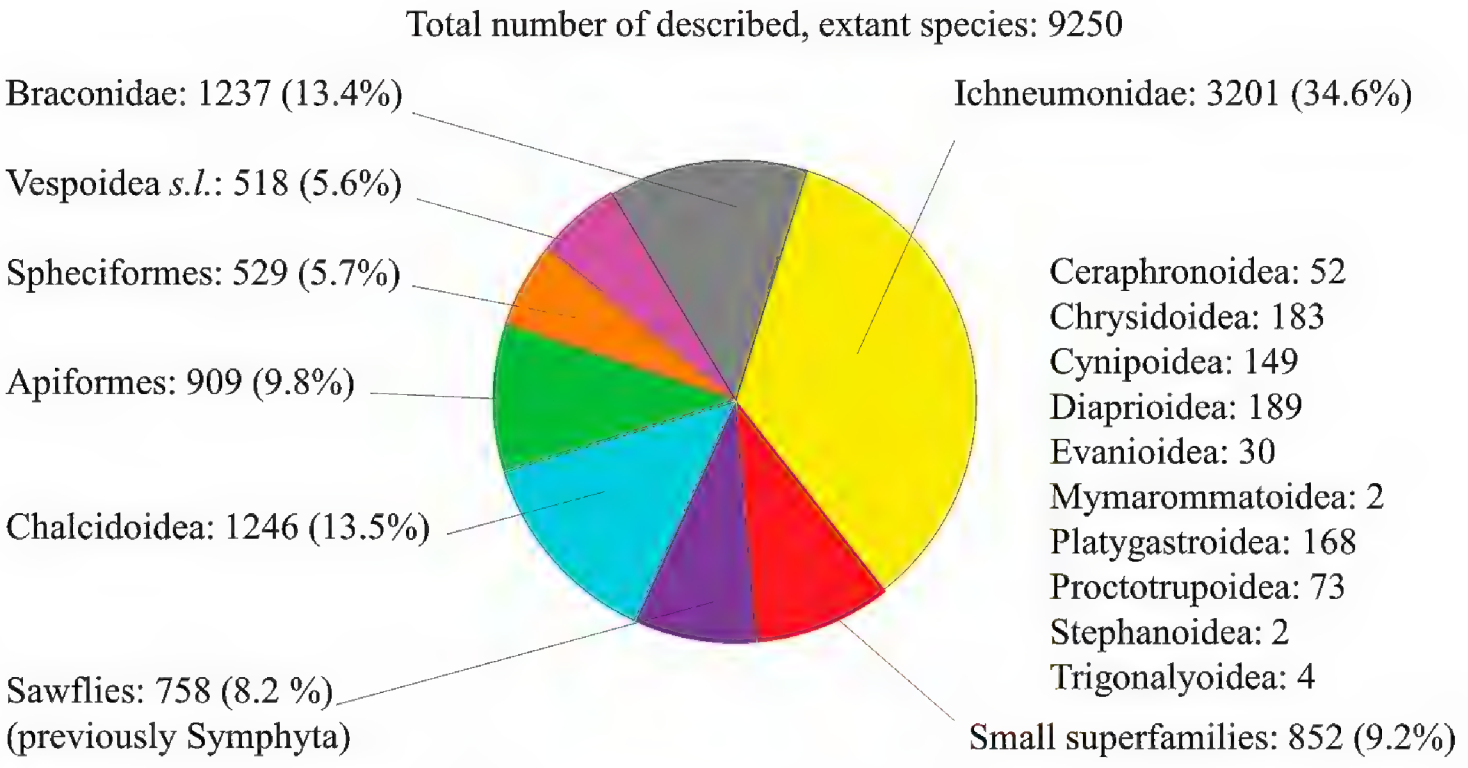

Figure 2. Number of species of Hymenoptera in northern North America by major taxonomic group as shown as a percent of the total species.

and Fig. 2). The sawfly superfamily Tenthredinoidea is the fourth largest with 641 species (6.9% of the total) and Vespoidea *sensu lato* is fifth (518 species: 5.6%). The largest families in northern North America are Ichneumonidae (3201, 34.6% of the total), Braconidae (1237, 13.4%), Tenthredinidae (573, 6.2%), Eulophidae (379, 4.1%) and Pteromalidae (309, 3.3%).

Within northern North America, the region with the highest recorded number of extant, described species of Hymenoptera is Ontario: 5322, 57.5% of the 9250 species (Fig. 1 and Table 2). Ontario is remarkable in that it is home to species in 82 of the 84 families found in northern North America. The only two that are absent are the sawfly family Anaxyelidae and the vespoid family Chyphotidae, both represented by a single species found only in southwestern Canada. The region with the next highest number of species is Quebec (4207, 45.5%), followed by British Columbia (4063, 43.9%). These three provinces contain areas of relatively high endemism within Canada, such as southern British Columbia's antelope-brush ecosystem and the Carolinian life zone of southern Ontario, both of which are northern extensions of ecozones more

Table 3. Summary of current and previous inventories of Hymenoptera for various regions/ countries in the Northern Hemisphere.

Geographic region / country	Described species	Land mass (million km²)	Species / million km²	Reference
Russia	15,290	17.1	894.2	Lelej et al. (2017), Belokobylskij et al. (2019)
Canada + AK + GL	9250	13.9	665.5	Current study
Canada	8933	9.98	895.1	Current study
Germany	8896	0.35	25,417	Dathe et al. (2001)
Finland	7577	0.34	22,285	FinBIF (2020)
Britain & Ireland	7764	0.31	25,045	Broad (2014)
Ontario	5322	1.08	4928	Current study

prevalent farther south (Scudder 2000; Richards et al. 2011). Greater sampling effort in these provinces certainly also contributes to these higher numbers (Langor 2019).

With respect to comparisons of the relative diversity of described species of Hymenoptera in northern North America versus some other parts of the Northern Hemisphere, some of these data are listed in Table 3. In terms of total species, Russia has many more species recorded: 15,290, 65.3% more compared to northern North America (Lelej et al. 2017, Belokobylskij et al. 2019), but the number of species per unit area is only about 34% higher (894.2 species / million km² for Russia compared to 665.5 for northern North America). The density of species in Canada (895.1) is almost exactly the same as Russia. Examining these data for smaller regions in the Northern Hemisphere, there is a trend that smaller areas generally have a higher number of species per unit area compared to large. For example, Ontario (current study) has 4928 species per million km², and even smaller areas like Germany (Dathe et al. 2001; Dathe 2004), Finland (FinBIF 2020), and the British Isles (Broad 2014) have much greater density of recorded species (25,417, 22,285 and 25,045 species per million km², respectively). Similar to the discussion above regarding Canada, these differences are largely a reflection of greater sampling effort and taxonomic expertise on the fauna of these smaller areas, but there is also likely an ecological component in that large parts of the Holarctic region are comprised of relatively homogenous vegetation types such as the boreal forest and Arctic tundra (Scudder 1979). This means that plant communities, herbivores and parasitoids in these ecozones are likely similarly homogenous. One would therefore expect a relatively high proportion of Hymenoptera species in these biogeographic realms to be widespread species, which would result in lower relative species diversity in large regions such as northern North America or Russia, i.e., many of the species found in Finland are likely also present and occupying similar habitats in Russia.

A comparison of the overall faunal composition of Hymenoptera in northern North America versus Russia and the British Isles is provided in Table 4. In general, the percentages of the major taxa are quite similar between northern North America and Russia, although northern North America has a much higher percentage of Ichneumonidae (34.6% of the total fauna in North America versus 24.3% in Russia). These differences might be a function of the fact that the Russian checklists included only estimates of numbers for three of the largest subfamilies of Ichneumonidae: Campopleginae,

Table 4. Comparison of the faunal composition of the Hymenoptera of northern North America (Canada+AK+GL) compared to Russia (Lelej et al. 2017, Belokobylskij et al. 2019) and Britain and Ireland (Broad 2014).

Taxon	Canada+AK+GL		Russia		British Isles	
	Species	% of total	Species	% of total	Species	% of total
SAWFLIES	758	8.2%	1546	10.1%	537	6.9%
APOCRITA						
Ceraphronoidea	52	0.6%	77	0.5%	92	1.2%
Chalcidoidea	1246	13.5%	2307	15.1%	1717	22.1%
Cynipoidea	149	1.6%	291	1.9%	216	2.8%
Diaprioidea	189	2.0%	162	1.1%	276	3.6%
Evanioidea	30	0.3%	44	0.3%	7	0.1%
Braconidae	1237	13.4%	3467	22.7%	1335	17.2%
Ichneumonidae	3201	34.6%	3709	24.3%	2578	33.2%
Mymarommatoidea	2	< 0.1%	2	< 0.1%	1	< 0.1%
Platygastroidea	168	1.8%	422	2.8%	362	4.7%
Proctotrupoidea	73	0.8%	78	0.5%	42	0.5%
Stephanoidea	2	< 0.1%	2	< 0.1%	0	< 0.1%
Trigonalyoidea	4	< 0.1%	8	0.1%	1	< 0.1%
Aculeata						
Apoidea: Apiformes	909	9.8%	1216	8.0%	260	3.3%
Apoidea: Spheciformes	529	5.7%	685	4.5%	125	1.6%
Chrysidoidea	183	2.0%	432	2.8%	80	1.0%
Vespoidea *s.l.*	518	5.6%	842	5.5%	135	1.7%
TOTALS	**9250**		**15290**		**7764**	

Cryptinae (including Phygadeuontinae) and Ichneumoninae. Additional research on these highly diverse, challenging groups may greatly increase the numbers of Ichneumonidae known from Russia. Conversely, there is a higher percentage of Braconidae recorded in Russia (22.7% of the total Hymenoptera fauna compared to 13.4% in northern North America). There are more differences between the composition of northern North America and the British Isles. The percentage of Chalcidoidea recorded in the British Isles relative to all species of Hymenoptera is considerably higher than in northern North America (22.1% of all species compared to 13.5%). This is likely a reflection of the more intensive effort on chalcidoid taxonomy in the British Isles relative to northern North America. In contrast, all groups of Aculeata have a much lower percentage of the total fauna in the British Isles compared to northern North America. For example, bees comprise only 3.3% of the total Hymenoptera species known in the British Isles compared to 9.8% in northern North America (Table 4). This difference is likely because of the relative lack of hot, dry habitats in the British Isles that support a high diversity of Aculeata such as are found in the prairie grasslands of southcentral Canada (Sheffield et al. 2014) and the Carolinian life zone of southern Ontario (Buck 2004).

The approximately 154,000 described species of Hymenoptera constitute about 8% of the estimated 1.9 million described species on the planet (Chapman 2009). The present checklist series will provide a much-needed inventory of Hymenoptera for an area that encompasses approximately 9.3% of the total world land mass. It is hoped that these data will foster a broad array of studies on this interesting, important and highly diverse group of organisms.

Acknowledgements

The list of people to thank for contributing to this project over the past dozen years is extensive. Especially, I would like to thank my Hymenoptera colleagues at the Canadian National Collection of Insects, Arachnids and Nematodes (CNC) who have provided scientific expertise on the taxa listed: Sophie Cardinal (bees), José Fernández-Triana (Braconidae), Gary Gibson (Chalcidoidea), Henri Goulet (sawflies and host-plant associations), John Huber (Chalcidoidea and Chrysidoidea) and Lubomir Masner (Ceraphronoidea, Diaprioidea, Platygastroidea and Proctotrupoidea). Many years of technical support at the CNC was provided by Diana Barnes who collated inventory files and checked and formatted literature references and manuscripts. More recently, Connor Lee added data to the inventory, especially primary types, and now Amber Bass has joined the Hymenoptera Unit and will undoubtedly continue to contribute to the series. Other technicians in the Hymenoptera Unit have been vital in supporting research including Lisa Bartels (Chalcidoidea), Caroline Boudreault (Braconidae), Teresa Martin (bees) and Jennifer Read (Chalcidoidea). Eric Maw was instrumental in writing scripts for our spreadsheet files that allowed checklists to be generated electronically from our inventory files. Other CNC scientists, technicians and the Collections Management team provided valuable input, especially through discussions of biodiversity in Canada. In addition, the project would not have been possible without a large team of summer students and contract workers who helped mine the collection and the literature for Canadian Hymenoptera records of Hymenoptera: Robert Fairchild, Hannah Cameron-Caluori, Chris Souliere, Shashi Juneja, Vanja Popovic, Joshua Hawley, Cassandra Stewart, Elina Iordanidi, Joseph Quisto, Leah Clarke, Cassandra Konecny, Lucy Bellemare, Shreya Nagavalli, Anna Grunsky and Jaclyn Eriksson. Rob Longair is also thanked for many discussions on Aculeata. Outside of the CNC, many other people are contributing to the series, most notably senior authors of several of the checklists: Matthias Buck at the Royal Alberta Museum (Chrysidoidea, Spheciformes and Vespoidea *sensu lato*) and Cory Sheffield at the Royal Saskatchewan Museum (bees). The latter is also thanked, along with David Langor (Northern Forestry Centre) for editing the Biota of Canada series which greatly complements this series. Particularly, the Biota of Canada series compiled family level data for Canadian DNA barcodes that are quoted in the individual checklists. This work was made possible by collaboration with the Centre for Biodiversity Genomics, University of Guelph (Jeremy deWaard). Many additional co-authors are contributing to the series: Y. Miles Zhang, University of Florida (Eurytomidae), D. Christopher Darling, Royal Ontario Museum (Perilampidae), István Mikó, University of New Hampshire (Ceraphronoidea), George Melika, National Food Chain Safety Office, Budapest (Cynipidae), Elijah Talamas, Florida State Collection of Arthropods (Platygastroidea) and James Glasier, Metis Nation of Alberta, Canada (Formicidae). In addition, the many curators of institutions who have lent material are recognized as well as a multitude of experts around the world who have answered specific questions (and will be thanked more specifically in the individual

checklists), as well as the many collectors and contributors to iNaturalist and BugGuide. Steve Marshall (University of Guelph) and Henri Goulet are gratefully acknowledged for providing photographs for many of the checklists. John Huber and Matthias Buck provided constructive comments to drafts of this manuscript. Gavin Broad (Natural History Museum, London) is thanked for leading the checklist series for the British and Irish Hymenoptera that is the model for this series and for reviewing the submitted manuscript. Simon van Noort (Iziko Museums of South Africa) is also thanked for reviewing this paper. Henri Savina (Toulouse) provided helpful advice regarding the TAXREF database of species recorded from Saint Pierre and Miquelon. Finally, Michael Ohl (Museum für Naturkunde, Berlin) is acknowledged for his willingness to publish this series in the Journal of Hymenoptera Research and the associate editors and reviewers who spent the time to review and help improve the checklists. This project has been funded by internal grants from Agriculture and Agri-Food Canada.

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